M2 - Internship offer
Advanced discrete optimization meets machine learning

Supervisors and location:

- ***Team:*** LIMOS - Clermont Auvergne INP
- ***Supervisor:*** Renaud Chicoisne, Maître de conférences, Recherche Opérationnelle. LIMOS, ISIMA
- ***Co-Supervisors:*** Pierre Latouche, Professeur des Universités, Statistiques, Machine Learning. LMBP, Université Clermont-Auvergne
  Rodolphe Le Riche, Directeur de recherche CNRS, Processus Bayesiens. LIMOS, Mines de Saint-Étienne.
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Context and project: Many experts believe that optimization is a key ingredient to the success of machine learning. In this internship, we aim at using the integer programming machinery and standard decomposition methods to solve a special class of maximum-likelihood optimization problems that arise in Machine Learning.

The problems at hand aim at maximizing a nonlinear likelihood function subject to sparsity constraints, (i.e. the regression model must involve no more than a fixed number of the input parameters). The former turns the optimization problem nonlinear, while the latter adds integer variables to our model.

While (e.g. [1-3]), a simple relaxation along with an EM algorithm can be employed for inference, we plan here to address the optimization task directly with no relaxation in order to improve the selection of the variables even further.

The resulting maximum-likelihood problem can be cast as a high-dimensional, mixed-integer nonlinear optimization program that can be solved via a tailored cutting plane algorithm combined with piecewise-linear approximation techniques. The supervisors have already written elements of solutions to the problem.

In this internship, the student will develop and also implement (in C/C++, R, or Python) solutions and algorithms for discrete optimization in Bayesian variable selection. Ideally, the implementation of our methodology should be applied to the meteorological data provided by our partner Instacrops in order to provide accurate frost event predictions (See e.g. [4]).

This internship is particularly recommended for students who are interested in doing a PhD on the subject after the internship. Generally speaking, at the core of this research field is the will to rely on strong optimization techniques to tackle existing and relevant models for machine learning and artificial intelligence. Therefore, this internship is for students in Operations Research.

This internship must 1) last a maximum of five months, starting as soon as possible, and 2) be the main topic of a Master's thesis.

Expected skills: The candidate should be a second year Master student in an Operations Research / Optimization program, with a strong background in mathematics and computer science.

References:

[1] Latouche, P., Mattei, P. A., Bouveyron, C., & Chiquet, J. (2016). Combining a relaxed EM algorithm with Occam's razor for Bayesian variable selection in high-dimensional regression. *Journal of Multivariate Analysis*, *146*, 177-190.

[2] Bouveyron, C., Latouche, P., & Mattei, P. A. (2018). Bayesian variable selection for globally sparse probabilistic PCA. *Electronic Journal of Statistics*, *12*(2), 3036-3070.

[3] Bouveyron, C., Latouche, P., & Mattei, P. A. (2020). Exact dimensionality selection for Bayesian PCA. *Scandinavian Journal of Statistics*, *47*(1), 196-211.

[4] Diedrichs, A. L., Bromberg, F., Dujovne, D., Brun-Laguna, K., & Watteyne, T. (2018). Prediction of frost events using machine learning and IoT sensing devices. *IEEE Internet of Things Journal*, *5*(6), 4589-4597.